Genetic algorithms can improve quantum simulations

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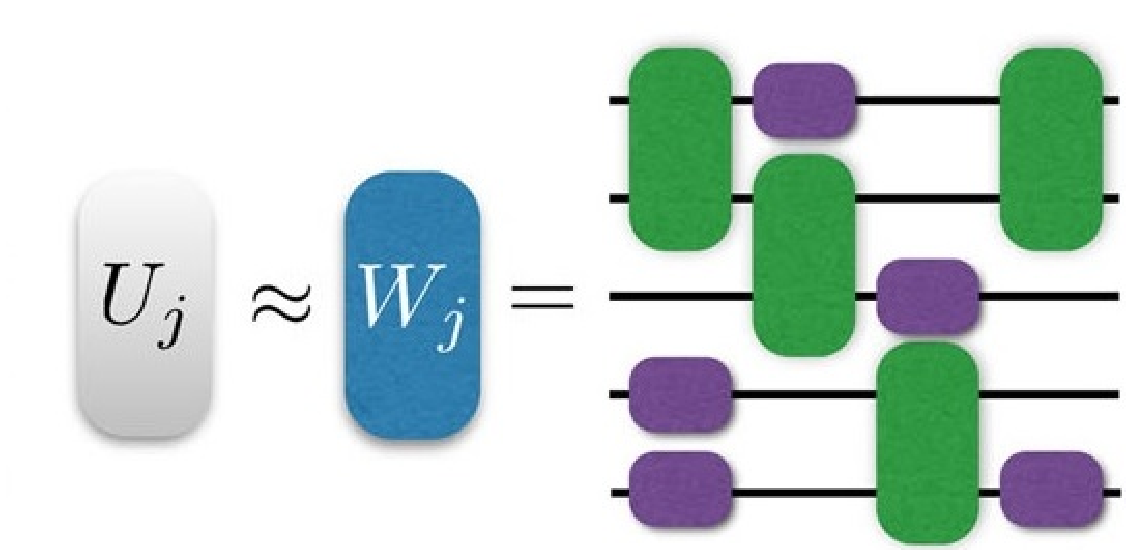

For the first time, researchers have used genetic algorithms to reduce quantum errors in digital quantum simulations. Credit: U. Las Heras et al. ©2016 American Physical Society

(Phys.org)—Inspired by natural selection and the concept of "survival of the fittest," genetic algorithms are flexible optimization techniques that can find the best solution to a problem by repeatedly selecting for and breeding ever "fitter" generations of solutions.

Now for the first time, researchers Urtzi Las Heras *et al*. at the University of the Basque Country in Bilbao, Spain, have applied genetic algorithms to digital quantum simulations and shown that genetic algorithms can reduce quantum errors, and may even outperform existing optimization techniques. The research, which is published in a recent issue of *Physical Review Letters*, was led by Ikerbasque Prof. Enrique Solano and Dr. Mikel Sanz in the QUTIS group.

In general, quantum simulations can provide a clearer picture of the dynamics of systems that are impossible to understand using conventional computers due to their high degree of complexity. Whereas computers calculate the behavior of these systems, quantum simulations approximate or "simulate" the behavior.

As a quantum technology, digital quantum simulations face many of the same challenges that confront the quantum computing field in general. One such challenge is information loss due to decoherence, which occurs when a quantum system interacts with its environment.

In order to protect quantum simulations against this loss, scientists use quantum error correction protocols, which provide a kind of back-up by storing information in entangled states of multiple qubits using quantum gates.

Storing information in an entangled state is a highly complex undertaking in the context of quantum error correction. For a system with just 4 qubits and 7 gates, the number of possible gate arrangements climbs into the trillions. Optimization techniques are used to sift through all of these designs and find the architecture that minimizes the error.

In the new study, the researchers demonstrated that genetic algorithms can identify gate designs for digital quantum simulations that outperform designs identified by standard optimization techniques, resulting in the lowest levels of digital quantum errors achieved so far.

Besides reducing errors due to decoherence, genetic algorithms can also reduce two other types of errors in digital quantum simulations. One type is the digital error created by the reduced number of steps used for approximating the algorithms. Another type of error arises from the imperfections in the construction of each of the gates.

As the researchers explain, one reason why genetic algorithms perform so well is their adaptability. Just like natural selection adapts to changes in environmental conditions, genetic algorithms continually adapt to different constraints imposed by different quantum technologies.

"Genetic algorithms are characterized by different features: adaptability and robustness," Solano told *Phys.org*. "Their adaptability allows for a flexible and clever technique to solve different problems in different quantum technologies and platforms. The robustness of the algorithm yields solutions that are resilient against errors, which allows us to cancel different error sources. [Due to these characteristics,] our work provides a new flexible tool in quantum simulations that allows us to reduce the required physical resources while keeping the operation precision. It also reduces the total decoherence and digital error by seizing on the different unavoidable error sources to mutually cancel each other."

Genetic algorithms already have been used in a wide variety of applications, such as finding the most efficient electrical circuit design, finding the mirror orientation that focuses the maximum amount of sunlight onto a solar collector, and designing antennas that are optimally tuned for detecting specific types of signals.

With help from genetic algorithms, future quantum simulations are expected to be useful for gaining a better understanding of complex physics, designing novel materials and chemicals, and solving problems in machine learning and artificial intelligence.

"These techniques could be used to solve problems that require resources unaffordable for present and future digital quantum simulations and gate-based quantum computing, by reducing and optimizing them," Solano said. "Also these techniques could easily decompose a problem into quantum gates adapted to different quantum platforms and quantum technologies. Finally, these techniques could also be applied to different problems in quantum computation and quantum information, such as the design of improved qubits, for instance. Needless to say, quantum simulations and quantum computing aim at the big picture: artificial intelligence, pattern recognition, design of new materials and chemicals, solving complex problems in aerodynamics, and quantum field theories, among many others."

More information: U. Las Heras *et al*. "Genetic Algorithms for Digital Quantum Simulations." *Physical Review Letters*. DOI: 10.1103/PhysRevLett.116.230504